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Research Article

A System of Remote Patients' Monitoring and Alerting Using the Machine Learning Technique

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Machine learning has become an essential tool in daily life, or we can say it is a powerful tool in the majority of areas that we wish to optimize. Machine learning is being used to create techniques that can learn from labelled or unlabeled information, as well as learn from their surroundings. Machine learning is utilized in various areas, but mainly in the healthcare industry, where it provides significant advantages via appropriate decision and prediction methods. The proposed work introduces a remote system that can continuously monitor the patient and can produce an alert whenever necessary. The proposed methodology makes use of different machine learning algorithms along with cloud computing for continuous data storage. Over the years, these technologies have resulted in significant advancements in the healthcare industry. Medical professionals utilize machine learning tools and methods to analyse medical data in order to detect hazards and offer appropriate diagnosis and treatment. The scope of remote healthcare includes anything from tracking chronically sick patients, elderly people, preterm children, and accident victims. The current study explores the machine learning technologies' capability of monitoring remote patients and alerts their current condition through the remote system. New advances in contactless observation demonstrate that it is only necessary for the patient to be present within a few meters of the sensors for them to work. Sensors connected to the body and environmental sensors connected to the surroundings are examples of the technology available.

1. Introduction

As the globe advances towards remote monitoring and real-time and rapid disease diagnosis, remote healthcare is a developing study area. Remote healthcare is divided into several groups (e.g., telehealth and mobile health), all of which refer to the use of technologies to monitor patients from outside hospital environments. The benefits of remote patient monitoring include initial and real-time identification of diseases, the ability to fully monitor patients, the

prevention of diseases adversely affecting and early deaths, cost savings in hospital admissions, a decrease in the number of hospital admissions, the way to access more accurate results while allowing patients to continue with their regular activities, and efficiency improvements in healthcare services. Patients with chronic diseases, individuals with mobility difficulties or even other disabilities, postsurgery patients, newborns, and older patients are among those who benefit from remote patient monitoring. All of these individuals have ailments that need constant monitoring. The

goal of excellent healthcare is to make everyday living as pleasant as appropriate for all patients [1].

Machine learning is a branch of artificial intelligence that has been upgraded (AI). Using artificial intelligence, we can create more intelligent machines. Machine learning is a strategy for learning from examples and experiences that is not explicitly changed. Rather than creating coding, the information is inserted into a generic algorithm, and reasoning is constructed depending on the information provided. Machine learning is utilized in several applications, including online searches, spam detection, banner advertising, and trading platforms [2]. Machine learning acquires similar significance and attention as big data and cloud computing by analyzing large amounts of information and automating the work of data scientists. Extensive scale informative collections are collected and analyzed in a variety of fields, ranging from design sciences to interpersonal organizations, business, biogenetic research, and security. The majority of conventional machine learning methods are designed for data that are completely stored in the system [3].

For patients who have been in an incident or sustained a severe injury, the time they are monitored electronically may be limited to the time they are now being transported to the hospital in an ambulance. Nonetheless, emphasis has been concentrated on ensuring a safe trip to the hospital, and remote monitoring aids in the provision of urgent medical treatments in extremely critical situations. Doctors can track the patient's improvement or preservation while also counselling paramedics who are physically with the patients as needed. A remote monitoring system's main ingredients are an information gathering system, information processing system, a healthcare end terminal, and a communication network. An information gathering system is made up of several sensors or devices with sensing devices that may transmit information wirelessly [4]. With the development of technology, sensors may no longer be limited to medical sensors; they may also be cameras or cell phones. This is due to current research on contactless techniques in which the gadgets do not make contact with the patient's body. Wireless sensor networks (WSNs) are the most prevalent kind of sensor utilized in noncontact techniques. These may be further subdivided into wireless body area networks (WBANs), body area networks (BANs), and personal area networks (PANs). An information processing system consists of a system capable of receiving and sending information as well as a processing unit/circuitry. A terminal in the hospital may be a computer (or a database) at the hospital, a specialized gadget, or the doctor's smartphone. The core communication network links the information gathering system to the information processing system, and the discovered information and conclusions are then sent to a healthcare professional that is linked to the system through the communication network.

The next section introduces some definitions and general architecture for remote patient monitoring systems, followed by advantages of RPM. Then, the essential components for RPM are discussed. Finally, the statistical analysis of the data is done, and then the work is concluded in Section 9.

2. What Is the Definition of Remote Patient Monitoring?

Remote patient monitoring, also known as telemonitoring and in-home tracking, is a collection of technologies and techniques that allow healthcare professionals to watch real improvements in a patient's health information from a distance and utilize it in a treatment protocol [5]. It is an essential element of the larger telehealth and e-health industries.

RPM concentrates on chronic illness individuals, postoperative patients, elderly citizens, and people from rural regions with restricted accessibility to healthcare. The RPM architecture shown in Figure 1 is a 3-layered architecture. These layers are classified as the patient layer, storage layer, and backend layer. The patient layer focuses on continuous monitoring of the patient. The storage layer stores data using cloud computing, and the backend layer is responsible for handling the information system.

The general architecture of RPM is shown in Figure 1. As per latest studies, when implemented to certain groups, remote monitoring can

(a) Minimize readmissions by 38%

(b) Decrease emergency department visits by 25%

(c) Increase patient satisfaction by 25%

(d) Cut expenses of care by 17%

(e) Enhance medication compliance by 13%

Considering the possible advantages, it is not surprising that about 88 percent of healthcare organizations have either engaged in or are contemplating investing in RPM technology. The major distinction between cloud computing and fog computing is that cloud computing is a complete system, whereas fog computing is a distributed decentralized architecture. To achieve their objectives, these innovations must develop a complete system that spans the whole RPM cycle [6].

3. The Advantages of Remote Patient Monitoring

There are many advantages of remote patient monitoring, which are listed as follows [7]:

3.1. Enhanced Care Quality. RPM provides patients and medical professionals with more meaningful patient information, which improves the overall performance and value-based treatment

3.2. Higher Levels of Literacy and Support. RPM provides patients with information and comments on their specific circumstances on a daily basis, educating and supporting them
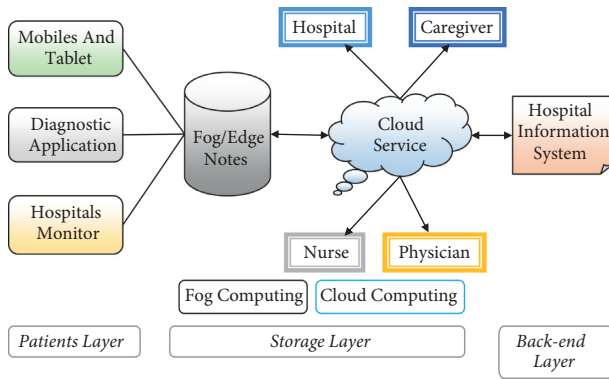
FIGURE 1: General architecture of RPM.

3.3. Patient Assurance. continuous supervision can provide patients with the confidence that any possible problems will be detected in a timely way

3.4. Enhances Accessibility to Healthcare. because RPM enables individuals to do basic health tests under their own, healthcare providers can treat additional patients

3.5. Enhances Patient Engagement. RPM technologies empower individuals to take an active part in controlling and analyzing their own health problems

However, there are some limitations as well for the remote patient monitoring systems. The major drawback lies in the unproven accuracy of the devices used. Also, the use of RPM is difficult for smaller medical facilities, as well as those who are living in rural and unreserved locations. Lack of provider engagement is another disadvantage of RPM.

4. Essential Factors of RPM Systems

A remote patient monitoring system is an example of a machine learning (ML) system. In the most typical scenario, it comprises 4 essential factors:

(a) A Bluetooth-enabled private health device
(b) A patient smartphone application
(c) Storage in the cloud
(d) Hospital-side application

4.1. A Bluetooth-Enabled Private Health Device. Without the supervision of a healthcare professional, advanced remote patient monitoring systems collect a large amount of healthcare information, ranging from heart rate to blood pressure. They may be sensors inserted under the skin or user-friendly devices such as an Apple watch or Fitbit. However, as previously stated, only wireless, noninvasive instruments monitoring common physiological indicators have FDA approval for remote use by hospitals at least until the COVID-19 epidemic is over [8].

The new FDA regulation covers the following RPM devices:

(a) Electrocardiographs (ECGs)
(b) Cardiac monitors
(c) Oximeters
(d) Audiometers
(e) Blood pressure devices
(f) Breathing frequency tracks
(g) Electronic stethoscopes

All wearables must communicate patient information to their healthcare professionals in some way, which is usually accomplished via the use of a specialized smartphone app. While there are many methods that may be used to transfer data from RPM equipment to smartphones, Bluetooth Low Energy (BLE) connection is the most common.

4.2. Patient Smartphone Application. A smartphone application that interacts with patients gathers information from wearables and smart sensors and sends it to clinic personnel [9]. This critical component of an RPM system must satisfy the following requirements:

(a) Bluetooth Low Energy (BLE) compatibility for information sharing between gadgets
(b) Adherence to the IEC 62304 safety standard, which defines criteria for the implementation of healthcare software and software embedded in medical equipment
(c) HIPAA compliance to ensure the security of protected health information (PHI)
(d) Protection against connection problems such as buffering techniques
(e) Integration with a healthcare provider's system through a secure API based on the FHIR industry standard to guarantee compatibility across various medical software solutions

In a way to involve patients, the app often includes interesting visualizations of input data, accessibility to education material, medical quizzes, medication management, and doctor-patient interaction capabilities (video, audio, or chat) [10].

4.3. Cloud Storage. The cloud store (database) often gets raw patient-generated information from the smartphone app. Some technologies, however, provide direct-to-cloud connection for gadgets, which implies that all recorded data are stored in the cloud. Patients do not need to acquire a specialized smartphone app in this scenario [11].

4.4. Hospital-Side Application. A hospital-side application, such as a patient application, must conform to HIPAA standards and healthcare exchange regulations [12]. Table 1 shows RPM online solutions that can be connected to the hospital's EMR system through an FHIR-based API to share data and prevent gaps in the information.

Table 1: How the RPM online solutions should be connected with a hospital's EMR system through an FHIR-based API to share data and prevent information gaps?

Report components	On a regular basis, the system stores all data and manually inputs the relevant information and delivers them to a physician.
Analytic components	BI technologies and information visualization methods are used to display real-time measurements as well as themes and patterns. They allow physicians to anticipate potentially dangerous occurrences and make educated treatment choices.
Notification components	If a decision-making support component detects danger signals, it informs a notification component, which produces an alert notification and notifies a doctor by SMS, e-mail, or in-app notice of an aberrant condition.
Decision support components	The vital sign information extracted from the storage site is evaluated to the physician-set input parameters.

RPM systems and their elements differ based on the application. Sometimes, a solution may not even need the use of linked medical equipment. Surveys are used for monitoring: each day, patients answer dozens of questions on a tablet and input various medical data (such as body temperature or heart rate) on their own.

5. Statistical Breakdown of the Data

This part gives a statistical breakdown of the search outcomes from several perspectives (different domains, differences in each year). Figure 2 depicts the distribution of published papers throughout the research investigation (2014 to 2019). As can be seen, numerous research studies quickly rise from 18% in 2014 to 33% in 2019. It demonstrates the expansion of the RPM study. Figure 3 depicts the distribution of the collected publications based on the illnesses addressed in the study. Including these statistics, RPM for the senior has the highest proportion (28%) followed by RPM for heart failure (26%). Other illnesses, such as cancer, hypertension, and postsurgical complications, account for a proximal percentage range of 8 to 14% [13].

6. Sensors for the Wireless Body Area Network (WBAN)

Sensors are important in the majority of RPM. They are seen as a link between the sufferer and the outside globe [14]. There are various sensors that have been used in the patient monitoring system. Pressure, force, airflow, temperature, and barcode sensors are the most common sensors found in medical devices. RPM utilized a variety of sensors to collect patients' vital signs and health information, such as EEG, ECG, and heart rate, as well as background information (room temperature, room oxygen level, etc.). Machine learning (ML) gadgets are utilized to send information across several networks [15]. This enables human-to-human and thing-to-thing communications through a network of sensors and gadgets. A wireless body area network is a collection of wearable sensors that are often connected to the body of a person using invasive and noninvasive methods. WBAN sensor nodes are divided into two kinds, which are as follows:
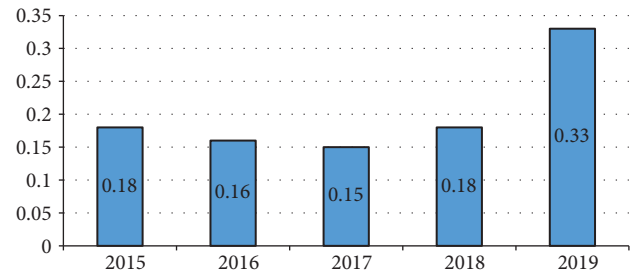
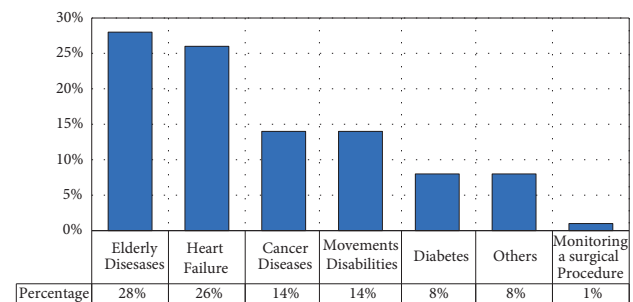Figure 2: Number of articles per year.

Figure 3: Distribution of RPM according to diseases.

6.1. *Implanted Sensors.* sensors that are placed within the body of the patient (under the skin).

6.2. *External Sensors.* sensors that are connected straight to the patient's skin or distanced by about 2–5 cm.

7. Wireless Body Area Network (WBAN) Challenges in RMS

Regardless of the benefits of WBAN sensors in RPM, they still have many difficulties and limits that influence their productivity and dependability; these issues are as follows.

7.1. *Data Mechanism for Communication.* The majority of healthcare systems must transfer information over local and worldwide networks utilizing wireless technologies such as ZigBee, Lora, and Bluetooth [16]. Every wireless technology has limits in terms of power, energy, and transmission range. ZigBee is thought to be ideal for small-area applications. The summary for these parameters is shown in Table 2.

Table 2: Summarization of the mechanism for communication.

Mechanism for communication	Consumption of power	Coverage	Frequency
Bluetooth	Medium	10 M	1 MHz
Wi-Fi	High	100 M	2.4 GHz
ZigBee	Very low	70–100 m	2.4 GHz

7.1.1. Information Security and Privacy. Because most patients who use RPM are worried about their health data, many research studies have focused on information privacy and security [17]. For instance, the authors suggested elliptic curve cryptography (ECC). ECC is a key-based data encryption technology. It relies on public and secret keys for decryption and encryption of internet usage. ECC is a security scheme that consists of three stages:

(1) Recognition of information skin and consumers

(2) Registration verifies the authentication stage and establishes a secret channel

(3) Verification of skin and customer communication, and the researchers noted that this design improves the system's dependability

7.2. Standardization and Inclusion. Because healthcare information is often large and heterogeneous, accessibility is essential. Interoperability in RPM operates on two fronts:

7.2.1. Sensor Interoperability. the capacity of embedded sensors and distant devices in an interconnected sensor unit to communicate with one another

7.2.2. Data Interoperability. integrate data from disparate providers (i.e., XML, CSV, SQL, etc.) and offer WSN interoperability assessments [18]

7.3. Interference. There are two kinds of interference in a WBAN system. Intrainterference is the most common in a single WBAN. Numerous studies have shown that flexibility time division multiple access (TDMA) is the best option for reducing interference and power consumption [19].

8. Healthcare Machine Learning (ML) Solutions for Remote Patient Monitoring

Machine learning has been evaluating as a new trend in the field of healthcare in this current era due to its ability to analyse the problem statement just like the human brain. Due to this ability, many technological companies are focusing on introducing machine learning for multiple healthcare sectors in order to reduce the human intervention for reducing human-based errors. Now, we study to look at machine learning (ML) companies that are focusing on remote patient monitoring systems.

8.1. Machine Learning and Sound for Remote Heart Monitoring. Machine learning techniques are used by organizations such as iRhythm and the French machine

learning company cardio logs to evaluate conventional electrocardiogram (ECG) data. Eko, located in Berkeley, California, was found in 2013. Its mechanisms move to a bit distinct rhythm. The company has received $27.8 million in reported financing, with the most recent injection of capital being $20 million Phase B in September. Eko has created two stethoscope-like instruments. When compared to a conventional stethoscope, the CORE provides 40x sound enhancement, while the DUO integrates sound with ECG recording. The latter is also available in the form of an at-home gadget that patients may use to monitor their vital signs [20].

8.2. Wearable Powered by Machine Learning for Remote Patient Monitoring. Present Health, a Scottish company established in 2015, has developed both hardware and software to offer insightful information on a patient's health through a worn wristband. The firm has reported $11.7 million in financing. Its technologies constantly evaluate a variety of vital indicators from its own device, including pulse rate, oxygen saturation, respiration rate, temperatures, and movements, but the platforms may also collect other data [21].

8.3. Intelligent Implant for Remote Patient Monitoring. Talking of India, ten3T, a Bengaluru company established in 2014, has received an unknown amount of funds, including a Venture round in April. It created the Cicer patches to allow for remote patient monitoring. The gadget measures vital indicators such as pulse, breathing, and blood pressure. Its analytics interpret the information in real time, delivering warnings when a fault is identified, but the system is also capable of identifying more minor changes with time. Because 75% of life-threatening incidents occur outside of the ICU, there are a number of cheap fruits [22].

8.4. Respiratory Status Remote Patient Monitoring. Feebris, a UK company, seems to be doing something comparable to Myia Labs, utilizing signal processing and machine learning techniques to derive clinical insights and even recommendations. The business, which was found in 2017, received about $1.4 million in a Venture round in May. Feebris, on the contrary, focuses on the most vulnerable groups, such as children and the elderly, in order to identify complicated respiratory diseases outside of a clinical environment. Figure 4 shows the architecture for the mobile app identifying several diseases using machine learning. The architecture shown in Figure 4 makes use of sensors and a mobile app for detecting various diseases for a patient. The sensors identify the symptoms from a patient's body, and the
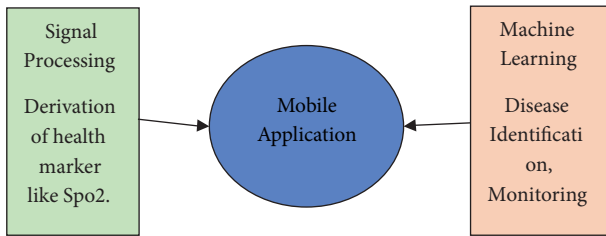
Figure 4: Mobile app identifying several diseases using ML.

machine learning algorithms process the symptoms and identify the disease. These signals then are transmitted to the mobile application along with the symptoms in an understandable form.

8.5. Using AI and Machine Learning to Transform Wearable Information into Healthcare Actions. May be Verily could add San Francisco-based Myia Labs to their expanding list of collaborations. Since its inception in 2017, the company has received $16.75 million in funding, including $10 million Series A in September. Myia monitors chronically sick patients using streams of personalized health information from wearable devices such as the Apple watch and Amazfit and then utilizes machine learning and other artificial intelligence methods to detect flare-ups before they occur [23].

9. Conclusion

This study has explored the definition of remote patient monitoring systems and their advantages; then, we have discussed the essential factors of remote patient monitoring very briefly. In this study, we examine the statistical breakdown of the data and more discussed the data collection. Then, in this study, we deeply analyse the wireless body area network (WBAN) challenges in RMS, and in concrete, this study suggests the system of healthcare machine learning (ML) solutions for remote patient monitoring. The research conducted can be proven very efficient in removing the flaws that current remote patient monitoring systems face, such as the accuracy of the devices used, the loss of information, and miscommunication between patients and doctors. The advance remote patient monitoring systems can be implemented using this research work that may lead to better healthcare systems in the future.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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